

PATENT

BAKER BOTTS L.L.P.
30 ROCKEFELLER PLAZA
NEW YORK, NEW YORK 10112

TO ALL WHOM IT MAY CONCERN:

Be it known that WE, JOHN R. MRUZ and RICHARD PALKER, citizens of the United States, residing in New York, County of New York, and Kings Park, County of Suffolk, State of New York, whose post office addresses are 59 Victor Drive, East Northport, NY 11731, U.S.A. and 6 Midvale Drive, Kings Park, NY 11754, U.S.A., respectively, have invented an improvement in

SWITCHABLE RF POWER DIVIDER/COMBINER

of which the following is a

SPECIFICATION

BACKGROUND OF INVENTION

[0001] The present invention relates to radio frequency (RF) power dividers/combiners, and particularly to a novel switchable power divider/combiner.

[0002] Power dividers are known to be functional for dividing a single RF signal into multiple RF signals or, reciprocally, for combining a plurality of phase-coherent RF signals into a single output RF signal. Such known power dividers/combiners are arranged with a fixed number of input/output ports and are designed to accommodate the fixed number of input/output ports.

NY02:91554.1

NY02:91554.1

[0003] Single-pole, N-throw RF switches are also known, for connecting a single common port to one of N output ports. Such switches usually connect only a single output port to the input port at any time, other than for brief intervals during switching.

[0004] It is an object of the present invention to provide an arrangement for a switchable RF signal divider/combiner which has impedance matched inputs and outputs. It is a further object of the invention to provide systems, such as RF power amplifiers, using one or more power combiners/dividers in accordance with the invention.

SUMMARY OF THE INVENTION

[0005] In accordance with the invention there is provided an RF signal divider/combiner comprising a single pole, N-Throw RF switch, where N is an integer of 3 or more. The switch is operable to connect up to N individual ports carrying RF signals to a common port. There is further provided a switchable impedance matching network having at least N-1 switch selectable matching elements which is arranged to provide selected impedance matching for the N-way RF switch according to the number of individual ports that are connected to the common port by the switch.

[0006] In a preferred embodiment the switch includes a planar inner conductor in an RF cavity, connected to the common port at one end and having a switch contact at a second end. A plurality of N switch reeds are moveable by electromagnets for selectively connecting the switch

contact of the inner conductor to any of the individual ports. There is further provided at least N-1 impedance matching switch reed for selective connection to the planar inner conductor.

[0007] In accordance with the invention, an RF power amplifier is provided having a switchable RF power divider connected between an input port and a plurality power amplifiers and a switchable RF power combiner for selectively connecting the output of the power amplifiers to an RF output port.

[0008] For a better understanding of the present invention, together with other and further objects, reference is made to the following description, taken in conjunction with the accompanying drawings, and its scope will be pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 is a block diagram showing an RF system having multiple parallel RF amplifiers.

[0010] Figure 2 is a schematic diagram of a single-pole four-throw RF switch.

[0011] Figure 3 is a plan view of the inner conductor arrangement of a switchable power divider in accordance with the present invention.

[0012] Figure 4 is a perspective view of the RF cavity of a switchable power divider in accordance with a preferred embodiment of the invention for use with the inner conductor arrangement of Figure 3.

[0013] Figure 5 is a perspective exposed view of the RF cavity assembly a preferred embodiment of a switchable RF power divider according to the present invention.

[0014] Figure 6 is a perspective view of an assembly of a switchable RF power divider in accordance with the present invention.

[0015] Figure 7 is a cross-sectional view of a portion of the Figure 6 power divider.

[0016] Figure 8 is a block and schematic diagram of an RF amplifier using power dividers in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] In connection with the present invention reference will generally be made to RF power dividers, it being understood that such dividers are reciprocal device and equally useful as power combiners. Accordingly, the term dividers should be construed to encompass devices applied as either dividers or combiners.

[0018] Figure 1 is a block diagram of a system which includes parallel power amplifiers 16A, 16B, 16C, 16D which receive coherent RF signals, generated by signal source 12 and divided in equal

91

PATENT

amplitude and phase relation by RF divider 14. The output signals from RF amplifiers 16 are provided to combiner 18 and thereafter to antenna 20.

9/1 pl.
cont [0019] Those familiar with RF circuits will recognize that in a conventional system of the type shown in Figure 1, proper operation requires that all amplifiers 16 be operating to normal specification, with equal amplifier power and phase. In the event one of the amplifiers, such as amplifier 16C, should fail, the result will be a possible impedance mismatch at divider 14 and a power combining impedance mismatch at combiner 18. The resulting signal loss will exceed the $\frac{1}{4}$ power loss normally associated with the failed amplifier, because of the impedance mismatch at the combiner. In the event that one of amplifiers 16 fails, or in the event that it is desired to disconnect one of the amplifiers 16, it is desirable to reconfigure power divider 14 and power combiner 18 to isolate the failed amplifier 16C from the other elements of the system.

[0020] Figure 2 is a schematic diagram of a conventional single-pole, N-throw ($N=4$) RF switch 22 having a signal input port 23 and switch selectable output portions 25A, 25B, 25C and 25D. In normal applications the switch reeds 24A, 24B, 24C and 24D are moved to connect only one of the output ports 25 to the input port 23. Because there is only a single connection at any time (except possibly during the switching process), assuming the load on the connected output port 25 is equal to the characteristic impedance of the transmission line and source 23, impedance match is achieved.

PATENT

250-250
[0021] If more than one of the output ports 23 of switch 22 were connected, the input impedance at input port 23 will be a function of the impedance of all connected output ports. Accordingly, assuming that the output ports are 50 ohm loads, and two output ports are connected, the impedance at input port 23 will be 25 ohms. If all switch reeds 24 are moved to the connected position, and 50 ohm loads are provided at each output port, the impedance of input port 23 will be $12\frac{1}{2}$ ohms. Accordingly, activation of more than one switch reed 24 will normally cause a significant change in the input impedance, normally causing a mismatch and power loss by reflection.

[0022] Figure 3 is a plan top view of the inner conductor and reed portions of an RF signal divider 32 in accordance with a preferred embodiment of the present invention. The Figure 3 drawing depicts the center conductor members of an RF switch assembly whose outer conductor is formed as an RF cavity 44 formed into a RF housing 42, as shown in perspective view in Figure 4. Figure 5 shows the inner conductors of Figure 3 in place within cavity 44 of housing 42.

92
[0023] The inner conductor portions shown in Figure 3 include a common input port 33, which is connected to a 50 ohm slab-line inner conductor 36 to be mounted within housing 42, as shown in Figures 4 and 5. Coaxial output ports 35A, 35B, 35C and 35D connect inner conductor 36 selectively to one or more of output ports 35. According to the number of output ports connected, an input signal provided to input port 33 is provided as an output signal to one or more output ports 35. Reeds 34 are mechanically moved between open or "off" positions and

PATENT

closed or "on" positions by electromagnets in a conventional manner as will be further explained.

a2
cont'd.

[0024] Those skilled in the art will recognize that when a single output port 35 is connected to input port 33 by one of switching ^{reads} reads 34, the load presented to input port 33 is a match, i.e., 50 ohm, impedance load. As additional output ports (35) are connected by switching of their respective switch reads 34, provisions must be made for impedance matching the input port 33 to the changed load condition.

[0025] To provide for impedance matching, switchable matching stub reads 37, 38 and 39 are ^{respectively} located at selected distances D1, D2 and D3 along slab transmission line 36 from the switching connection point. Each impedance matching reed 37, 38, and 39 has a respective impedance matching length L1, L2 and L3, which is selected to provide reactive impedance matching for the power divider when 2, 3 or 4 of output ports 35 are connected to transmission line 36 by their respective switching reads 34.

[0026] In a representative embodiment arranged to operate at a frequency band of approximately 1805 to 1870 MHz dimensions D1, D2 and D3 and lengths L1, L2 and L3 are appropriately selected as follows:

[0027] Any two outputs D3 = .619" L3 = .583"

[0028] Any three outputs D2 = .523" L2 = .833"

[0029] Any four outputs

D1 - .459"

L1 = .947"

[0030] In the arrangement of Figure 3 impedance matching reed 38 is activated when two output ports are connected, impedance matching reed 39 is activated when three ports are connected and impedance matching reed 37 is activated when four output ports are connected.

sub
a3
P030904-070378.0107

[0031] Reference is made to the cross-sectional view of Figure 7, which illustrates a typical configuration for operation of reeds 34 and impedance matching reeds 37, 38 and 39 of the preferred embodiments of Figures 3 through 5. As shown in the perspective assembly view of Figure 6, RF housing 42 is provided with a cover plate 46 to provide an RF assembly 48. A solenoid mounting plate 50 is secured to cover plate 46 and provided with solenoids 52 for activating the switch and impedance matching reeds. A circuit board 60 is conveniently mounted above solenoids 52, and includes integrated circuits 66 for providing driving currents in accordance with supplied logic signals representing the desired state of the power divider, provided to terminal 62, and using DC power supplied to terminals 64.

[0032] The cross-sectional view of Figure 7 shows a solenoid 52 for driving an armature 68 in a downward direction in response to supplied current. Armature 68 engages nonconducting activating pin 70 to move reed 34 from the open switch position shown in Figure 7 to a position connecting output terminal 35 to slab-line center conductor 36.

sub
a4

[0033] Those skilled in the art will recognize that the switchable power divider of the present invention can be advantageously used in connection with a multiple solid state amplifier device

NY02:91554.1

NY02:91554.1

PATENT

as shown in Figure 8. In connection with such amplifiers it is possible to provide a variable power output signal by selecting less than all of the four power amplifiers 16 for producing a combined output signal. In this case control logic 76 can control which of amplifiers 16 are to be activated and, accordingly, set the condition of divider 32 and combiner 32' using driver circuits 60. By control of the switching reeds 34 and the impedance matching reeds 37, 38 and 39, the number of output signals from the divider 14 or input signals to combiner 18 can be varied, while maintaining impedance match. *as shown in Fig. 3*

[0034] As an additional feature, it is possible to provide a power amplifier system which will have a "fail soft" characteristic. Monitor couplers 72 are provided at the output of each individual amplifier 16, and the monitor signal is provided to detectors 74. Control logic 76 responds to a failure of any of amplifiers 16 to discontinue operation of that amplifier, and reconfigure power divider 14 and power combiner 18 for operation with the remaining three amplifiers. Accordingly, the amplifiers continues to function with reduced power output

[0035] While the present invention has been described with respect to a four-way power divider, those skilled in the art will recognize that the principles of the invention are applicable to N-way dividers and appropriate N-1 matching reads can be provided. In addition, those skilled in the art will recognize that a system of the type shown in Figure 8 can be provided for normal operation with less than all of the amplifiers 16, for example three amplifiers, with the fourth amplifier being a stand by amplifier to be substituted in the event of a failure of one of the other units.

NY02:91554.1

NY02:91554.1

[0036] While there as been described what is believed to be the preferred embodiment of the invention, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the present invention, and it is intended to claim all such changes and modifications as fall within the true scope of the invention.

1. The first step is to identify the problem. This involves understanding the current situation and what needs to be changed.